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# Microbial Endophytes of Tuber Crops

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**Abstract**

Endophytes are symbiotic micro-organisms which comprise mainly selected *taxa* of bacteria and fungi that colonize internal tissues of plants. They have been acknowledged to be beneficial to the host plant in diverse ways such as induced biotic and abiotic stresses, increase in biomass, nitrogen fixation, protection against pathogens, among others. But where the immunity of the host plant is compromised, they can become pathogenic. In order to colonize host plant tissues and compete favourably with other microorganisms, endophytes produce a variety of secondary metabolites like antibiotics, antifungal compounds, toxins, enzymes, among others. Tuber crops are major source of energy giving food next to cereals, but little information is available regarding how endophytes interact with them, which is necessary for their survival. Symbiotic interaction of endophytes with tuber crops have been documented as antagonistic against some major plant pathogens like *Phytophthora infestans, Sclerotium rolfsii*, *Pythium aphanidermatum* and *Rhizoctonia solani* while a good number of bacteria and actinomycetes participated in nitrogen fixation and starch degradation, hence, are reportedly potential source of bio-fertilizers and heat-stable amylases used in major industrial process like starch hydrolysis. This review therefore attempts to discuss the various benefits of tubers-endophytes interaction and the need to intensify research to tap into the immersed potentials of endophytes associated with tuber cultivation yet to be explored.

***Keywords: Microbes, Endophytes, Tubers***

## Introduction

Endophyte was first used by a German Botanist and father of plant pathology named Anton de Bary in 1886; he described endophytes as micro-organisms such as bacteria, actinomycetes and fungi which colonize internal tissues of most plants (Shubhransu *et al*., 2017). Endophytes interaction with host plant is symbiotically asymptomatic (Hallmann *et al*., 2017). While the host plants provide accommodation and nutrition to the endophytes, the latter on the other hand induce immune responses that help in the survival of the host plant to various biotic and abiotic stresses through the production of various proteins and secondary metabolites (Bamisile *et al*., 2018; Kumar and Dara, 2021). Tuber crops such as cassava, sweet potato, yams and yam beans serves as major source of income, staple foods and household food security especially in developing countries in the tropics (Lebot, 2019). They are acknowledged as the second most important energy giving food crop next to cereals (Nayar, 2014). Although endophytes have been reportedly studied in some of these crops, there is still insufficient information regarding their huge benefits to these tubers during interaction. This review, therefore focused on the benefits confered by a wide range of endophytic bacteria, actinomycetes and fungi during their interactions with tubers and the need to intensify research to explore the huge potentials of endophytes yet to be discovered.

## Mechanisms of Endophytes colonization of Host plant

The mechanisms by which endophytes colonize host plant as documented in relevant literatures are itemized thus:

***Entry within the host plant***: Endophyte access plant endosphere usually through the rhizosphere, soil or when inoculated as an inoculum. In general, colonization of roots by endophyte such as bacteria, actinomycetes and fungi begins with the recognition of specific compounds that are released from the root tissue (Lugtenberg and Dekkers, 2019). This was illustrated when; tomato roots produces certain chemo-attractants compounds like amino acids that attract *Penecilium fluorescens* strain WCS365 to its roots (Faure *et al*., 2019). The bacterium response to these chemo-attractants and actively colonizes the roots using a two-component system, the first component consisting of a single protein with input and output transmembrane domains lacks receiver domain, while the second component has only phosphotransfer histidine kinase (Heeb and Haas, 2011).

***Transcriptional Regulators***: Physiological responses like transport processes, metabolism of sugars and amino acids, pilus synthesis, quorum sensing(QS), and motility are regulated by transcriptional regulators (Maddocks and Oyston, 2008). The role of transcriptional regulators in root colonization of Canola plant by endophytic bacterium as documented by Kumar *et al.* (2017) and English *et al.* (2010) involves the introduction of a transposon upstream the *hns* gene in *Enterobacter cloacae* UW5 resulting in acceleration of the transcription level about twofold, showing increased roots colonization than the wild-type strain in a direct competition assay.

***Autoinducers***: Autoinducer molecules used for bacterial quorum sensing (QR) are necessary during endophyte colonization (Kumar *et al.,* 2017). This is supported from the report of Suarez-Moreno *et al.* (2010), wherein it was observed that QS mutant strains of *B. kururiensis* M130 failed to show effective root and aerial rice tissue colonization when compared with the wild type. Also, expression of *AttM* lactonase in genetically modified rice endophyte *Azospirillum lipoferum* B518 developed by Boyer *et al.* (2018) promote the synthesis of proteins involved in transport and chemotaxis which control functions related to root colonization.

***Niche adaptation and adhesion***: The ability of endophytes like bacteria, actinomycetes, fungi, among others, to rapidly modify and integrate their metabolic pathways within the range of available nutrients is essential for their survival and growth inside the plant tissue (Kumar and Dara, 2021). A research documented by Kumar *et al.* (2017) on gene expression analyses of root-colonization by *Pseudomonas putida* KT2440, show that there was an upstream regulation of genes involved in stress adaptation and metabolism in the rhizosphere of the corn plant since certain up stream regulated genes were involved in the uptake of readily available compounds like amino acids, polyamines, dipeptides, and aromatic compounds as well as genes of enzymes related to stresses such as glutathione peroxidase and fatty acid cis-trans isomerase and detoxification of proteins such as putative efflux transporters. Also, survival of certain endophytes in the roots of plant growing in dense vegetation requires adaptation to anoxic conditions. This fact is reported by Brune *et al.* (2010) in rice plants which make heterogeneous oxic or anoxic interfaces allowing rhizobacteria and endophytes carry out fermentation processes resulting to lactic acid and ethanol accumulation in root tissues. Furthermore, cell surface components like polysaccharides, pili, and adhesins are reportedly involved in mediating endphytes like fungi and bacteria adhesion to root surfaces of plants (Hori and Matsumoto 2010, Kumar *et al.,* 2017).

***Colonization***: During Plant tissue colonization, the rhizosphere microfloras are distinguished from soil microbial community by a process called *rhizodeposition* because plant developmental processes and secretory activities are entangled within the root system (Dennis *et al.,* 2010). Rhizodeposition also involves the release of a specialized population of cell known as root cap border cells in the rhizosphere which are major contributors to the “rhizospheric effect” (Hawes *et al*., 2010, Kumar *et al*., 2017). Rhizodermis cells secrete a wide range of compounds such as nucleosides, organic acids, purines, sugars, vitamins, amino acids, phytosiderophores and inorganic ions while the root caps produces polysaccharide mucilage (Dakora and Phillips, 2012, Bamisile *et al*., 2018).

## Endophytes of Selected Tubers

***Yam endophytes***: The diversity of endophytes observed in Yam tuber is reportedly poor (Shubhransu *et al.,* 2017). Though, bacterial strains namely; *Erwinia pyrifoliae* and *Erwinia Pantoea* complex have been isolated from yam tubers by Zhang *et al*. (2010) and Omoregie *et al*. (2019), in some cases simultaneous inhabitation of dark septate endophyte and arbuscular mycorrhizae fungi which are good symbionts have also been observed in Yam tuber (Maggirwar *et al*., 2013). However, endophytic colonization remains a big constraint in the commercial propagation of yam tuber by tissue culture technique due to unhealthy competition with the explant (Shubhransu *et al.,* 2017). To eliminate such bacterial endophytes in tissue culture, antibiotics like rifampicin are used, while fungicide mixture of lambda-cyhalothrin and man-cozeb/carbendazim eliminates the fungal endophytes (Wakil and Mbah *et al.,* 2012).

***Sweet potato endophytes***: Quite a number of endophytic bacteria, fungi and actinomycetes from sweet potato have been isolated, identified and their biological importance in agriculture documented (Adachi *et al*., 2012). For instance, eleven bacterial endophytes of the genera *Phyllobacterium, Enterobacter*, *Rhodanobacter*, *Pseudomonas*, *Rahnel-la, Xanthomonas* and Stenotrophomonas have been isolated from sweet potato stems. Among these endophytes, *Pseudomonas, Rahnella* and *Enterobacter* produced higher amount of Indole acetic acid (IAA) which have plant growth promoting effect. Plant growth promoting (PGP) activity was also observed in fungal endophytes of sweet potato. A study conducted by Hipol (2012) in Baguio city Philippines, show that majority of the fungal endophytes namely *Fusarium oxysporum, Emeri-cella nidulans*, among others isolates from six healthy looking leaves, stems and roots of the sweet potato exhibited plant growth promoting effect. The diazotrophic nature of some bacterial endophytes like *Pantoea* spp., *Klebsiella* spp and non-diazotropihic *Enterobacter* spp also has been verified by their ability to grow in nitrogen free media (Elbeltagy *et al*., 2011, Adachi *et al.,* 2012). Two actinomycetes endophytes isolates namely *Streptomyces avermitilis* MA-4680 and *Streptomyces griseus* NBRC 13350 isolated from roots of sweet potato were shown to have antagonistic activity towards pathogenic *Streptomyces scabies* which causes potato scab disease (Hend and Abeer, 2013). Similarly, thirty two actinomycetes isolated from the rhizosphere of an organic native potato (*Solanum tuberosum L.*) in Peru were documented to be antagonistic against *Phytophthora infestans* which cause potato blight disease by producing antifungal compound like carbazomycin, and also hydrolyse starch and celloluse in their growth medium due to the production of amylases and cellulases (Chumpitaz *et al.,* 2020).

***Yam Bean endophytes*****:** The presence of some endophytic bacteria and actinomycetes has been documented to exhibit symbiotic association with Yam bean. For instance, twenty five isolates belonging to the genera *Rhizobium* and *Bradyrhizobium* isolated from root nodules of yam bean tuber, established effective nodules containing bacteroid cells in their peribacteroid membrane which confer nitrogen-fixing potential to the plant (Fuentes *et al.,* 2012, Sorensen, 2016). Actinomycetes like *Nocardiopsis* sp, *Kitasatospora recifensis*, among others reportedly dominant in yam bean tubers were discovered as viable source of thermostable amylolytic enzymes which are essential during starch hydrolysis in the industry (Stamford *et al*., 2011, Shubhransu *et al.,* 2017).

***Cassava endophytes*****:** The existence of endophytes in cassava have long been suspected before now due to the fact that asymptomatic cassava plants grown in the same field with symptomatic cassava plants frequently showed a wide range of variation in root yield. Also, root yield of low-yielding virus-free cassava plants of traditional clones may be increased by meristem culture, furthermore, the root yield of meristem culture-derived cassava plants decreased uniformly sharply under field conditions coupled with the long growing cycle of cassava allowed infection and dissemination of diseases (Shubhransu *et al.,* 2017). Therefore, a couple of endophytic bacteria species, funga species and actinomycetes have been isolated from asymptomatic parts of cassava plant. The bacterial isolates include; *Hyphomicrobium, Bacillus, Psuedomonas, Paenibacillus* among others. The fungal isolates include; *Septoria nodurum*, *Fusarium oxysporum*, *Colletotrichum gloeosporioides*, *C. graminicola*, *Alternaria termissima*, *Trichoderma* sp., *Botrytis sp*., *Torula sp*., *Nigrospora sp*., among others, while the actinomycetes isolates include *Streptomyces malaysiensis, Streptomyces avermitilis and Streptomyces griseus*, etc (Rivera *et al.,* 2013, Khucharoenphalsan *et al.,* 2016). Both detrimental and beneficial effects of endophytes have been observed in cassava plant depending on the method of inoculation. For example a fungus *Curvularia sp*. was found to be detrimental when inoculated by spraying, but beneficial when inoculated by immersion or puncturing on plantlets and callus tissues of cassava variety M Col 2215 (Shubhransu *et al.,* 2017). This phenomenon may be due to the pathogenic nature of some strains of *Curvularia sp* towards many plants e.g. *Curvularia* r*hizoctonia* behaved as endophyte in the leaf and stem but it induced necrosis in roots. A couple of bacterial endophytes have significant antagonistic effect on many virulent plant pathogens (Chauhan *et al*., 2013). For instance 25% of the cultures belonging to *Bacillus species* produce an antifungal compound pumilacidin, which show strong antagonistic activity against plant pathogenic fungi like *Rhizoctonia solani*, *Pythium aphanidermatum* and *Sclerotium rolfsii* in a study conducted by DeMelo *et al.* (2009) in healthy roots, stems and leaves of six cassava varieties. Similarly, twenty endophytic bacteria isolates from surface sterilized cassava stems of which *Pseudomonas* species show *in vitro* bacteriostatic activity against cassava bacterial blight pathogen (Purnawati and Nirwanto, 2013). It is further observed that the endophytic actinomycetes-*Streptomyces malaysiensis* isolates of cassava plant produces secondary metabolite called Indole Acetic Acid (IAA) which inhibited the growth of the pathogenic fungus *Phytophthora sp.* at significant levels (Khucharoenphalsan *et al.,* 2016).

## Future prospects of endophytes-tubers interactions

In spite of the immersed above contribution of endophytes towards the survival and growth of these tubers considered in this review, many important tuber crops are still to be looked for such an interaction and the mechanisms by which such interaction occurs. Reports regarding such symbiotic interactions is still lacking in literature. Although, in a recent study documented by Shubhransu *et al. (*2017), endophytic colonisation in tuber crops like taro, greater yam and elephant foot yam were explored but the mechanisms by which endophytes interact specifically with these tubers have not been studied or even understood hence, no updates is available at the moment. It is expedient that research efforts be made towards studying the mechanisms by which endophytes specifically colonize these tuber crops as it will help in improving the knowledge of how they interact and possibly enhance the production output of these tuber crops in the nearest future.

## Conclusion

Endophytes association with tuber crops confer enormous benefits, as they have been shown to induced systemic resistance to biotic and abiotic stresses, increase in biomass, nitrogen fixation, protection against pathogens, among others in these crops. A couple of endophytic fungi, actinomycetes and bacteria may be applied as potential biofertilizers due to their nitrogen-fixing ability, and they can be used as antibacterial agents and fungicides in tuber crops with minimal environmental risks due to their ability to produce secondary metabolites. Embarking on thorough investigation in the biodiversity of endophytes may create new possibilities for the biological control of many tuber crop diseases. Hence, concerted effort is required to intensify the research for isolation and utilization of large numbers of endophytic microbes from tuber crops for better yield in the nearest future.

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